Claims

1. A magnetic resonance imaging apparatus comprising:

a phantom disposed in static magnetic field;

an eddy current measurement means which takes an image of the phantom by repeatedly executing an eddy current measurement sequence composed of an application of a test gradient magnetic field having an application time longer than a time constant of an eddy current as a measurement object and having a predetermined intensity in a predetermined axial direction and of a repetition in a plurality of times of a pulse sequence which is started in response to rising up or falling down of the test gradient magnetic field while changing phase encoding amount thereof, and successively measures a plurality of image data containing magnetic field variation information due to eddy current induced by rising up or falling down of the test gradient magnetic field in a unit of the repetition time of the pulse sequence; and

compensation current calculating means which determines from the image data obtained in the repetition time of a current value to be flown into a magnetic field variation compensating coil at a time when taking an image of a subject and for compensating the eddy current.

2. A magnetic resonance imaging apparatus

according to claim 1, wherein the eddy current measurement means executes the eddy current measurement sequence in both positive and negative polarities of the test gradient magnetic field and performs subtracting calculation between the image data obtained.

3. A magnetic resonance imaging apparatus according to claim 1, wherein the eddy current measurement means includes a pulse sequence portion which repeatedly excites in a short repetition time nuclear spins within a predetermined region in the phantom and renders the nuclear spins in a state of steady state free precession.

4. A magnetic resonance imaging apparatus according to claim 3, wherein the pulse sequence portion which renders the nuclear spins in a state of steady state free precession is executed in succession with the repetition of the pulse sequence for taking images of the phantom.

5. A magnetic resonance imaging apparatus according to claim 1, wherein the image data containing the magnetic field variation information is phase image data.

6. A magnetic resonance imaging apparatus according to claim 1, wherein the test gradient magnetic field is applied in its actual value.

7. A magnetic resonance imaging apparatus

according to claim 1, wherein the test gradient magnetic field is applied in its effective value.

8. A magnetic resonance imaging apparatus according to claim 7, wherein the test gradient magnetic field applied in its effective value is contained in a form of respective pulse like gradient magnetic field in the pulse sequence repeatedly executed.

9. A magnetic resonance imaging apparatus according to claim 1, wherein the pulse sequence repeatedly executed is a gradient echo sequence.

10. A magnetic resonance imaging apparatus according to claim 1, wherein the eddy current measurement means is performed by separately applying the test gradient magnetic field in three orthogonal axes of gradient magnetic field application directions.

11. A magnetic resonance imaging apparatus comprising: a magnetic field generating means which respectively generates static magnetic field and gradient magnetic field in a space where a subject is placed; a signal transmission system which generates high frequency magnetic field for exciting nuclear spins in atoms constituting tissue of the subject; a signal receiving system which detects echo signals generated from the subject by mean of the high frequency gradient magnetic field; a signal processing system which reconstructs an image of the tissue of the subject by making use of the detected echo signals and a control

means which controls the magnetic field generation means, signal transmission system, signal receiving system and the signal processing system according to a predetermined sequence, wherein

the control means is provided with as the pulse sequence a calibration pulse sequence including a pulse sequence group repeated in a plurality of times in a predetermined repetition time which includes a step of applying a test gradient magnetic field after causing to generate an echo signal through application of the high frequency excitation pulse and application of phase encoding gradient magnetic field and read out gradient magnetic field and executes the calibration sequence of two kinds in total which are formed by changing the polarity of the test gradient magnetic field with a plurality of phase encoding values, and

the signal processing system forms a phase difference image from a set of echo signals obtained through execution of the calibration pulse sequence of the two kinds as well as calculates magnitude of eddy currents induced by the test gradient magnetic field and time constants thereof based on the phase difference image.

12. A magnetic resonance imaging apparatus according to claim 11, wherein the calibration pulse sequence is constituted by a first pulse sequence group repeated in a plurality of times in a predetermined

repetition time which includes a step of applying a test gradient magnetic field after causing to generate an echo signal through application of the high frequency excitation pulse and application of phase encoding gradient magnetic field and read out gradient magnetic field and a second pulse sequence group repeated in a plurality of times in a predetermined repetition time under application of a same phase encoding amount which includes a step of measuring an echo signal after causing to generate the echo signal through application of the high frequency excitation pulse and application of phase encoding gradient magnetic field and read out gradient magnetic field, and

the signal processing system executes the first pulse sequence group and the second pulse sequence group in plurality of times while changing the phase encoding amount, forms the phase difference image from the echo signals obtained in the second pulse sequence group as well as calculates magnitude of eddy currents induced by falling down of the test gradient magnetic field and time constants thereof based on the phase difference image.

13. A magnetic resonance imaging apparatus according to claim 11 or 12, wherein the control means performs the measurement of the echo signals with the pulse sequence group including the test gradient magnetic field, and

the signal processing system forms the phase difference image from the echo signal data obtained through the pulse sequence group including the test gradient magnetic field as well as calculates magnitude of eddy currents induced by rising up of the test gradient magnetic field and time constants thereof based on the phase difference image.

14. A magnetic resonance imaging apparatus according to any one of claims 11 through 13, wherein the control means measures the magnetic field variation due to the eddy currents in a predetermined time resolution by controlling the repetition time.

15. A method of compensating magnetic field variation due to eddy current induced by application of gradient magnetic field comprising the steps of:

(1) repeating in a plurality of times in a predetermined repetition time under application of a same phase encoding amount a process of causing to generate an echo signal through application of a high frequency excitation pulse and application of phase encoding gradient magnetic field and read out gradient magnetic field,

(2) applying a test gradient magnetic field after generation of the echo signal in the process at least some of the repetitions among the plurality of repetitions,

(3) collecting the echo signals in the process

where the test gradient magnetic field is applied and/or the process where the test gradient magnetic field is not applied,

(4) collecting a set of data of the echo signals by executing the steps (1) through (3) while changing the phase encoding amount,

(5) further collecting another set of data of the echo signals by executing the steps (1) through (4) while changing the polarity of the test gradient magnetic field,

(6) preparing respective phase images by making use of respective sets of data of the echo signals collected in the steps of (4) and (5),

(7) taking a subtraction of the phase images to form a phase difference image, and

(8) calculating a compensation value for compensating the magnetic field variation due to the gradient magnetic field based on the phase difference image.

16. A method of compensating magnetic field variation due to eddy current induced by application of gradient magnetic field according to claim 15, wherein the step (8) includes the steps of calculating a first order gradient component and a polarization component from the magnetic field variation at two points in the space of the static magnetic field and performing a non-linear fitting with regard to the first

order gradient component and the polarization component to decompose the respective components into arbitrary number of time constant components τ and amplitude A for every time constant.

17. A magnetic resonance imaging apparatus comprising: a magnetic field generating means which respectively generates static magnetic field and gradient magnetic field in a space where a subject is placed; a signal transmission system which generates high frequency magnetic field for exciting nuclear spins in atoms constituting tissue of the subject; a signal receiving system which detects echo signals generated from the tissue of the subject through application of the high frequency gradient magnetic field; a signal processing system which reconstructs an image of the tissue of the subject by making use of the detected echo signals and a control system which controls the magnetic field generation means, signal transmission system, signal receiving system and the signal processing system according to a predetermined sequence, wherein

the control system is provided with a calibration pulse sequence which is based on a pulse sequence of gradient echo method and is constituted by a first calibration pulse sequence in which is executed in a plurality of times while changing encoding amount of respective phase encode gradient magnetic field by a

predetermined amount, a group of a first pulse sequence group in which a first unit pulse sequence constituted by an application of a predetermined high frequency excitation pulse, application of phase encode gradient magnetic field and read out gradient magnetic field and after causing to generate an echo signal through these applications, application of a test gradient magnetic field having a first polarity is repeated in a plurality of times in a predetermined repetition time (TR)and of a second pulse sequence group following the first pulse sequence group in which a second unit pulse sequence constituted by removing the application of the test gradient magnetic field from the first unit pulse sequence is repeated in a plurality of times in a predetermined repetition time (TR') and by a second calibration pulse sequence in which is executed in a plurality of times while changing encoding amount of respective phase encode gradient magnetic field following that in the first calibration sequence, a group of a third pulse sequence group in which a third unit pulse sequence constituted by an application of a predetermined high frequency excitation pulse, application of phase encode gradient magnetic field and read out gradient magnetic field and after causing to generate an echo signal through these applications, application of a test gradient magnetic field having a second polarity is repeated in a plurality of times

in a predetermined repetition time (TR)and of a fourth pulse sequence group following the third pulse sequence group in which a fourth unit pulse sequence constituted by removing the application of the test gradient magnetic field from the third unit pulse sequence is repeated in a plurality of times in a predetermined repetition time (TR').

18. A magnetic resonance imaging apparatus according to claim 17,wherein the eddy current component induced at a time when the test gradient magnetic field applied rises up is measured from the difference between a phase image obtained from echo signals in the first pulse sequence groups among the first calibration pulse sequence and a phase image obtained from echo signals in the third pulse sequence groups among the second calibration pulse sequence, and the eddy current component induced at a time when the test gradient magnetic field applied falls down is measured from the difference between a phase image obtained from echo signals in the second pulse sequence groups among the first calibration pulse sequence and a phase image obtained from echo signals in the fourth pulse sequence groups among the second calibration pulse sequence and.

19. A magnetic resonance imaging apparatus according to claim 17,wherein the phase encode gradient magnetic field applied during the first through the

fourth unit pulse sequences is applied while changing the encoding amount in one axial direction by a predetermined amount.

20. A magnetic resonance imaging apparatus according to claim 17, wherein the phase encode gradient magnetic field applied during the first through the fourth unit pulse sequences is applied while changing the encoding amount in two axial directions by a predetermined amount.

21. A method of compensating magnetic field for a magnetic resonance imaging apparatus comprising the steps of:

applying onto a region of interest a first calibration pulse sequence in which is repeated in a plurality of times while changing encoding amount of respective phase encode gradient magnetic field by a predetermined amount, a group of a first pulse sequence group in which a first unit pulse sequence constituted by an application of a predetermined high frequency excitation pulse, application of phase encode gradient magnetic field and read out gradient magnetic field and after causing to generate an echo signal through these applications, application of a test gradient magnetic field having a first polarity is repeated in a plurality of times in a predetermined repetition time (TR) and of a second pulse sequence group following the first pulse sequence group in which a second unit pulse sequence

constituted by removing the application of the test gradient magnetic field from the first unit pulse sequence is repeated in a plurality of times in a predetermined repetition time (TR′),

applying onto the same region of interest a second calibration pulse sequence in which is repeated in a plurality of times while changing encoding amount of respective phase encode gradient magnetic field following that in the first calibration sequence, a group of a third pulse sequence group in which a third unit pulse sequence constituted by an application of a predetermined high frequency excitation pulse, application of phase encode gradient magnetic field and read out gradient magnetic field and after causing to generate an echo signal through these applications, application of a test gradient magnetic field having a second polarity is repeated in a plurality of times in a predetermined repetition time (TR) and of a fourth pulse sequence group following the third pulse sequence group in which a fourth unit pulse sequence constituted by removing the application of the test gradient magnetic field from the third unit pulse sequence is repeated in a plurality of times in a predetermined repetition time (TR′),

calculating a first order gradient component and polarization component in the eddy current component induced at a time when the test gradient magnetic field

applied rises from the difference between a phase image obtained from echo signals in the first pulse sequence groups among the first calibration pulse sequence and a phase image obtained from echo signals in the third pulse sequence groups among the second calibration pulse sequence,

calculating a first order gradient component and polarization component in the eddy current component induced at a time when the test gradient magnetic field applied falls down from the difference between a phase image obtained from echo signals in the second pulse sequence groups among the first calibration pulse sequence and a phase image obtained from echo signals in the fourth pulse sequence groups among the second calibration pulse sequence, and

calculating a value of compensation current to be flown into a coil inducing an eddy current at a time of image measurement based on the calculated respective first order gradient components and polarization components.